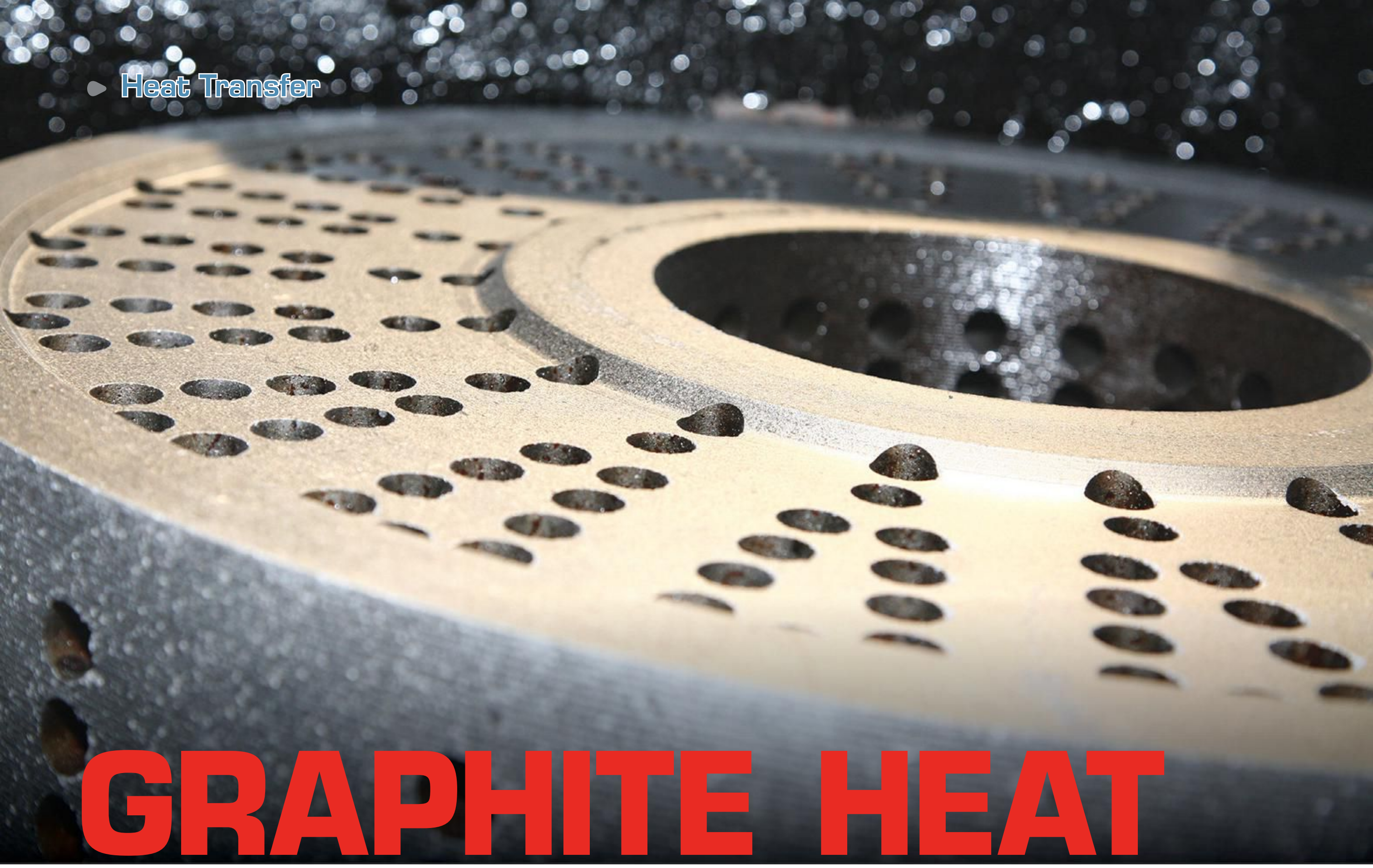

GRAPHITE HEAT EXCHANGERS

Handle Corrosive Applications

Available graphite grades and mechanical designs allow graphite heat exchangers to replace metal alloys and exotic metals in some applications.

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Graphite heat exchangers are well suited and cost effective for highly corrosive processes used in industries such as chemicals, metallurgy and pharmaceuticals. With steady progress in the number of available graphite grades and mechanical designs, graphite heat exchangers are making inroads into areas long held by expensive metal alloys and exotic metals with design pressure up to 350 psi and design temperature up to 2700°F (1482°C).

Three main types of graphite heat exchangers are common today:

- Shell and block (round or cubic).
- Plate and gasket.
- Shell and tube.

Generally, the block (figure 1) and plate types are restricted to smaller sizes, low flows and low-to-moderate heat loads. The shell-and-tube designs are best for larger sizes, high flows and fouling applications such as fertilizer manufacture.

In a block- or cubic-type heat exchanger, holes are drilled in a cylindrical or cubical graphite block to form the flow passages for both the cold and hot streams. The blocks are stacked one over the other with gaskets in between and then inserted into a steel shell. The gaskets are sealed by a unique spring-loaded system that exerts a compression force on the blocks. A multi-pass arrangement is possible on the tube side by suitably partitioning the headers and individual graphite blocks.

The shell-and-tube type is similar in construction to the conventional designs used in the industry, except that the tubes and plates are made of graphite. PTFE gaskets are used to seal flow passages, and a special graphite cement is used to seal tube-to-tube sheet joints.

Graphite Materials and Grades

One of the unique features of graphite technology is the ability to make a number of graphite grades to suit a wide range of application needs in a cost-effective way. Unlike alloys and exotic metals that are easily corroded, graphite is resistant to media that has contaminants such as chlorides and fluorides.

Graphite grades are assigned based on their performance with respect to the severity of the fluid medium from the standpoint of corrosion, pressure and temperature (figure 2). High quality impregnated graphite is achieved through the following steps.

Procurement of Raw Graphite. Grain size and density are the key quality indicators of raw graphite, along with mechanical strength. Smaller grain sizes indicate higher mechanical strength and cost more.

Graphite Impregnation. Graphite in its raw form is not impermeable, and fluids under pressure can seep through the raw graphite. Therefore, the first step to make raw graphite usable is to impregnate it with a suitable medium. Typical impregnation materials include corrosion-resistant plastic resins (phenolic or PTFE) or even carbon for the highest temperature applications (figure 3).

Deep and full PTFE impregnation is the most advanced impregnation process. Generally, impregnation involves four steps:

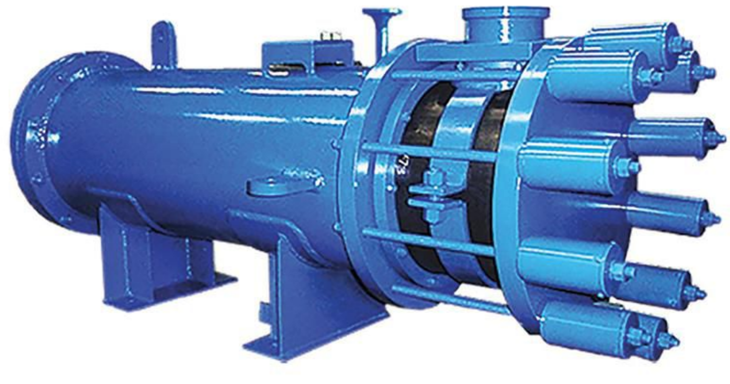

FIGURE 1. Graphite-block heat exchangers are suited use with corrosive materials. Generally, the block and plate types are restricted to smaller sizes, low flows and low-to-moderate heat loads.

- Heating to drive off vapors/gases from the voids in the raw graphite, then vacuuming the materials to extract gases from the void spaces.
- Heating the resin to the proper temperature to obtain the desired properties. The correct heat profile helps ensure the fluid will penetrate into the voids of the graphite.
- Applying the right pressure for the resin to penetrate the inter-grain spaces of graphite.
- Applying heat to allow polymerization of the resin.

Testing of Impregnation Quality. After impregnation, the residual porosity is detected through bubble tests under pressure to make sure that the impregnated graphite is impervious.

Impregnation effects the following changes in the raw graphite:

- Improves the mechanical strength of the raw graphite with phenolic resin.
- Reduces the thermal and shock resistance. Higher grain sizes have more void volume and, therefore, require more impregnation material. Consequently, they suffer higher degradation in thermal and fatigue resistance. This issue is solved using ultra-fine-grain graphite.

Phenolic impregnation is good for most chemical media; however, it cannot be used in strong alkaline or oxidative envi-

	Formulation 1	Formulation 2	Formulation 3	Formulation 4
Type of Graphite	Standard	Fine/Ultra-Fine Grain	Fine/Ultra-Fine Grain	Standard/Fine/ Ultra-Fine Grain
Impregnant	Phenolic	Phenolic	PTFE	Carbon
Relative Mechanical Resistance	1	1.5 to 3	1.5 to 1.8	1.5 to 2.5
Corrosion Resistance	Good	Better	Excellent	Excellent
Thermal Shock Resistance	Low	Better	Excellent	Excellent
Recommended For	Mild operating conditions (pressure, temperature, corrosion)	Higher pressure and temperature; frequent thermal cycles	Highest corrosion (oxidative media)	Highest corrosion and temperature (non-oxidative media)
Maximum Temperature	355°F	430°F	530°F	930°F / 2700°F

FIGURE 2. Graphite grades are assigned based on their performance with respect to the severity of the fluid medium from the standpoint of corrosion, pressure and temperature.

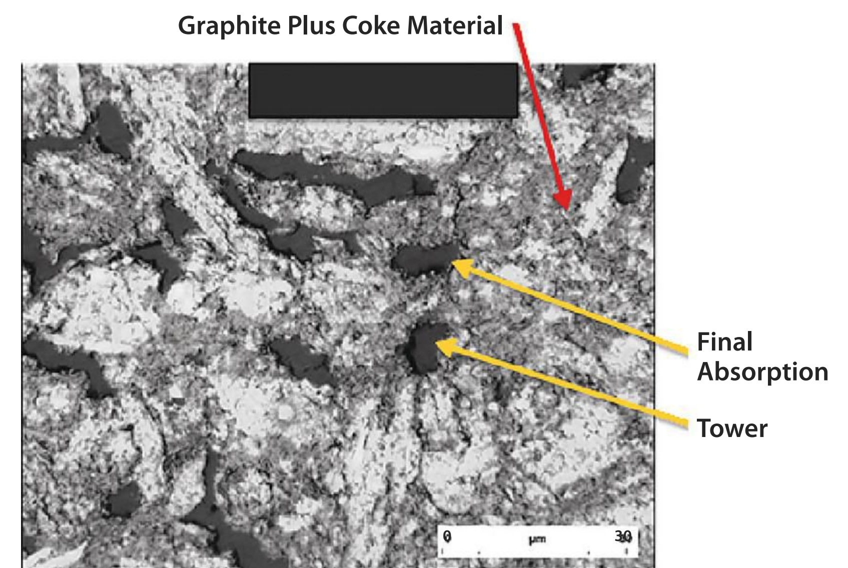

FIGURE 3. A micro view of resin-impregnated graphite can be seen here. The first step to make raw graphite usable is to impregnate it with a suitable medium such as a corrosion-resistant plastic resin (phenolic or PTFE) or even carbon.

ronments. In addition, some solvents and organic oils cause swelling of the resin. For example, it is not recommended for oxidative mediums such as nitric acid and sulfuric acid greater than 70 percent concentration and 300°F (149°C). Similarly, it cannot be used in applications where potash or caustic soda is present that would increase the pH above 11.

Carbon impregnation is not adapted for oxidative media. However, it greatly improves thermal shock resistance and temperature resistance in non-oxidative media with a possible temperature of 2700°F (1482°C).

PTFE impregnation has a wide-ranging resistance to most of the corrosive environments, oxidative, higher pH or alkaline and all solvents. In addition, it offers better thermal shock and fatigue resistance. For example, it can handle up to 96 percent sulfuric acid concentration at temperatures of 300°F (149°C). This material is a multi-purpose one and is used extensively for batch manufacturing of chemical compositions from fine chemistry to pharmaceutical.

Graphite Exchangers Put to Use in Process Applications

Several industries utilize graphite heat exchangers in their applications. Two examples — steel pickling and sulfuric acid heating and cooling — are described below as example cases.

Steel Pickling. One of the key applications of graphite heat exchangers is carbon and stainless steel pickling (figure 4). Steel parts from production lines after manufacture are dipped in acid baths for pickling. Pickling is a metal surface treatment. The process removes impurities such as stains, inorganic contaminants and rust or scale from metals. The process includes a solution called pickle liquor, which contains strong acids and removes surface impurities.

The acid baths consist of several tanks in a row at temperatures between 180 and 200°F (82 and 93°C), usually maintained by steam heating from typical graphite heat exchangers. The pickling solution for carbon steel is a mixture of hydrochloric and sulfuric acid. For stainless steel, it is a mixture of hydrofluoric and nitric acid.

Equipment Design Features

Traditional graphite heat exchangers suffer sensitivity to external mechanical stresses such as vibrations, water and steam hammer. Uneven flange tightening also may reduce product life cycle. One manufacturer's design avoids such drawbacks with several key features. They include:

- The system prevents pressure surges due to water hammer in piping system.
- A spring system eliminates mechanical stress variations during thermal cycling.
- Block drilling resists water or steam hammer and increases block mechanical resistance.
- Design prevents failure at piping connection.

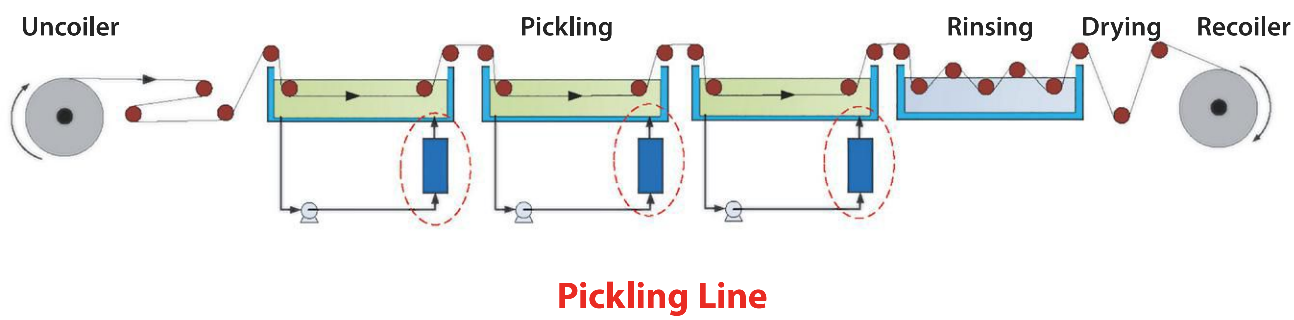

FIGURE 4. One of the key applications of graphite heat exchangers is carbon and stainless steel pickling. Steel parts from production lines after manufacture are dipped in acid baths for pickling.

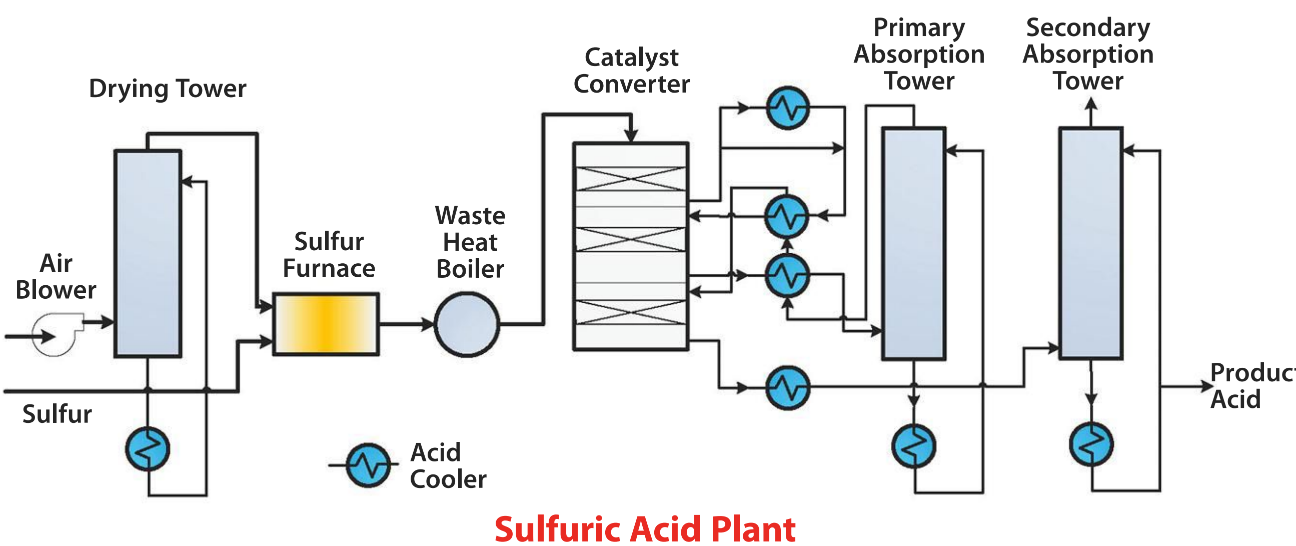

FIGURE 5. The process used for sulfuric acid production requires several tanks or towers that store the sulfuric acid in different concentrations.

Phenolic resin is the preferred choice for carbon steel pickling; however, phenolic resin cannot be used with nitric acid. Rather, PTFE impregnation of the graphite is required.

Sulfuric Acid Heating and Cooling. Sulfuric acid is perhaps the most ubiquitous compound used by the chemical industry. It makes hundreds of compounds found in nearly every industry. The annual worldwide production of sulfuric acid is around 200 million tons. Close to 50 percent of it is used for producing phosphoric acid for fertilizer production. The United States produces 36 million tons of sulfuric acid annually.

The process used for sulfuric acid production requires several tanks or towers that store the sulfuric acid in different concentrations (figure 5). The tanks or towers used in the process must be maintained between 80 and 90°F (27 and 32°C). For the average 1,000 tons/day, the combined heat rejection from the four towers ranges from 40 to 50 MW(th). This heat is sometimes recycled to the process through BFW heating for steam production. Low level heat is usually rejected to the heat sink. With sulfuric acid stream in the cooler, graphite costs less than metal alloys.

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